REMARKS

Claims 1-33 and 38-75 are in the application. Claims 1, 2, 11, 24, and 31 are in independent form. Claims 1-3, 6, 11, 15, 19, 24, 26-29, and 31-33 are amended. Claims 34-37 are canceled. Claims 38-75 are added.

In response to the restriction requirement, applicants have elected claims 1-33 and canceled claims 34-37 without traverse.

The Examiner has objected to the specification. In response, Paragraph #0001 has been amended to update the status of the applications. With respect to the abstract, applicants have added GaAs, indium phosphide, or single crystalline sapphire, which are also claimed. Applicants request, therefore, that this objection be withdrawn.

Claims 1 and 11-18 stand rejected under 35 USC 103(a) as being unpatentable over Piwcyzyk et al. in view of Cutler et al. and further in view of Lundquist et al. Applicants respond to this rejection as follows.

The Examiner states that "Piwczyk et. al. ('797) teach the basic claimed process of laser processing of thin bodies of silicon using a Q-Switched Nd:YAG pulsed laser beam (wavelength is shorter than 400 nm) having a spot diameter of 25 μm (see col. 7, line 38 and col. 9, lines 15-20) and a pulse energy of 500 μJ (col.4, line 40)."

Applicants have amended claims 1-3 and 11 to indicate that the laser output is generated at a repetition rate of greater than 5 kHz. Applicants have also amended claims 1, 2, and 11 to recite gallium arsenide instead of GaAs for consistency.

Piwczyk et al. ('797) employ a Spectra-Physics PRO-290 Q-switched Nd:YAG laser at a very low PRF (50 Hz) to process thin bodies of silicon. Under normal operating conditions the Nd:YAG laser oscillates at room temperature on the strongest $^4F_{3/2} \rightarrow {}^4I_{11/2}$ transition at 1.0641 μm, and the fundamental wavelength operation is limited to wavelengths longer than 0.939 μm. (For verification if desired, the Examiner is directed to Table 2.6, "Main room-temperature transitions in Nd:YAG", Solid-State Laser Engineering, W. Koechner, (Springer-Verlag, 1976, New York) which describes the well-known to the art fundamental laser wavelengths for Nd:YAG.)

Piwczyk et al. do not suggest employment of nonlinear optical techniques, such as harmonic conversion through the employment of nonlinear optical elements, for the conversion of the fundamental wavelength output from a Q-switched Nd:YAG laser to harmonic wavelengths that are less than 400 nm, such as 266 nm or 355 nm, for example.

The Examiner states that "Further, Piwczyk et al. ('797) teach a plurality of pulses having a high repetition rate of 5-10kHz used to cut silicone substrates having a thickness of 700 microns and forming a kerf (see col. 4, lines 1-3 and 30-35)."

Applicants note that in col. 4, lines 1-3, Piwcyzk et al. refer to prior art use of a copper vapor laser operated at this pulse repetition frequency, and not to the cutting of silicon using the method of Piwczyk et al. In fact, Piwcyzk et al. teach away from use of such laser system and parameters for the laser processing of silicon by stating that "...the kerf cavity created by the laser cutting action is rapidly filled in with SiO_2 slag so that the cut edges are glued shut." (See col. 3, line 65 through col. 4, line 10.) Skilled persons will recognize that this prior art method is not a useful laser process and does not result in useful silicon processing such as the formation of a useful curvilinear kerf. Applicants further note that the 700 micron thick substrates were subjected to the slow repetition rate of the 1064 Nd:YAG and not the copper vapor laser.

With respect to the preferred focused spot size to be employed, applicants note that Piwczyk et al. teach a method that "...directs the laser beam to the cylindrical lens and the latter converts the beam into an elongated narrow spot pattern, e.g., a spot measuring about 300 μm x 25 μm and focuses it through the glass window 28 onto the exterior surface of the silicon tube 10" (see col. 7, lines 35-40) and " ...when using a short pulse Nd:YAG laser to cut silicon, it is preferred to use a narrow elongated beam spot having a maximum width in the range of 40-150 microns" (see col. 9, lines 23-27). Piwczyk et al. ('797) also teach that "While a circular beam spot pattern may be used advantageously with other lasers and the present invention, an elongated narrow spot pattern is preferred for the purpose of maximizing cutting speed" (see col. 9, lines 18-21). Applicants note that applicants' original claims recite a spot area of <u>less</u> than 25 μm, which is less than the minimum spot dimension called out by Piwczyk et al. Applicants also note that while elongated spots could be employed to make a curvilinear kerf, such spots might not be preferred for making tight turns in such kerfs.

The Examiner states that Piwczyk et al. ('797) teach "a pulse energy of 500 μJ (col. 4, line 40)." However, col. 4, line 40 reads "[T]he energy per pulse was 500 mJ..."

500 millijoules is equivalent to 500,000 microjoules (μJ). The lamp pump design constrains the Spectra-Physics PRO-290 1064 nm laser to operate at very low frequencies (typically < 100 Hz). The very low pulse repetition frequencies of such lasers produce very high pulse energies, such as the production of 1064 nm output at nearly 1 Joule (1,000,000 microjoule) levels. Although the 500 mJ parameter is covered by the now claimed range of "greater than 100 μJ," applicants note that the completely different scale suggests a different process, particularly in view of the other different parameters.

Applicants also note that although Piwczyk et al. describe processing hollow silicon tubes, Piwczyk et al. do not appear to teach laser processing of gallium arsenide, indium phosphide, or single crystalline sapphire substrates.

In view of the foregoing, Piwczyk et al. provide little teaching of value that could be combined with any reference to suggest the invention as claimed. Piwczyk *et. al.* ('797) merely describes improvements to U.S. Patent No. 4,51,035 of Carlson et al., which use a Q-switched 1064 nm Nd:YAG laser for laser processing of silicon. Carlson et al. was described in applicants' patent application as relevant prior art. Therefore, Piwczyk et al. do not suggest the invention as claimed in any one of claims 1 and 11-18.

Despite the limited relevance of Piwczyk et al., applicants note that they have amended the independent claims 1, 2, and 11 to recite a PRF of greater than 5 kHz.

With respect to claims 1, 11, 17, and 18, and Cutler et al. and Lundquist et al., neither Piwczyk et al. nor Lundquist et al. provide any motivation for combination with Cutler et al., who do teach a laser controller including fast and slow translational actuators. In Piwczyk et al., the intention is to make straight cuts (without any curvilinear elements) into a hollow silicon tube, so a system like that of Cutler et al. would be wasteful.

Lundquist et al. teach a sequential laser raster scanning technique for processing ceramic wafers in which "[I]n the preferred process, the laser is pulsed as the laser spot is moved along a first scan line across the surface of the wafer to form the trench. The laser spot is then moved in a direction generally perpendicular to the first scan line a distance less than the laser beam diameter, and then pulsed while the laser spot is scanned along a second line generally parallel to the first scan line" (col. 2, lines 15-22). Accordingly in Lundquist et al., the intention is to make straight scan cuts (without any curvilinear elements) into TiC/Al_2O_3, so a system like that of Cutler et al. would be wasteful. Applicants further note that the only overlap that seems to be mentioned in Lundquist et al. is between consecutive scan lines. Lundquist et al. do not appear to mention a bite size or

give any other indication of overlap between adjacent laser pulses. Applicants also note that neither Cutler et al. nor Lundquist et al. appear to mention a PRF of greater than 5 kHz. Therefore, Piwczyk et al. in view of Cutler et al. and/or Lundquist et al. do not suggest the invention as claimed in any one of claims 1, 11, 17, and 18.

With respect to claims 12-14, the Examiner states that Piwczyk et al. "teach the use of a gas cover during laser processing to avoid slag formation, lip formation and peel back of the kerf edge (see col. 2, lines 30-35)." There is no such mention of such subject matter at this location. However, Piwczyk et al. do appear to require the use of a noble gas or vacuum chamber connected to a turbomolecular pump and a gas manifold and a purge gas to minimize debris. (See col. 4, lines 45-53 and Figs. 1B-1G.) Piwzyck et al. also teach that slag is significant problem when performing the process in air. "[I]n contrast, cutting in air produced a kerf that developed as a round "bowl" shape with a significant buildup of slag and a heat affected zone" (col. 5, lines 47-49). "[C]utting in air essentially terminated at a depth of about 50 microns using the Spectra-Physics Nd:YAG laser mentioned above." (See Fig. 1A and col. 5, line 49-51.) Applicants note that applicants' Figs. 3 and 4 show no such chamber and indicate that applicants' process can be performed in air. Moreover, because claims 12-14 are dependent on a claimed process that is significantly different from the disclosed process of Piwczyk et al., Piwczyk et al. do not suggest the invention as claimed in any one of claims 12-14.

With respect to claims 15-16, the Examiner states that Piwczyk et al. "teach a plurality of pulses having a high repetition rate of 5-10kHz that form a kerf" and "teach a curvilinear profile when laser cutting silicon in air (see col. 5, lines 45-50)." This is simply incorrect as discussed above with respect to repetition rate, straight line scanning, and Piwczyk et al.'s process. Moreover, because claims 15-16 are dependent on a claimed process that is significantly different from the disclosed process of Piwczyk et al., Piwczyk et al. do not suggest the invention as claimed in any one of claims 15-16.

In view of the foregoing, applicants request that the rejection of claims 1 and 11-18 be withdrawn.

Claims 19-33 stand rejected under 35 USC 103(a) as being unpatentable over Piwczyk et al. in view of Cutler et al. and further in view of Lundquist et al. and Elliot et al.. Applicants respond to this rejection as follows.

The significance of Piwczyk et al. in view of Cutler et al. and further in view of Lundquist et al. have been described above. Elliott et al. teach a glass vacuum chuck for aligning and holding a wafer during processing. Elliott et al. also teach "a method of aligning, including forming alignment marks on the back of the wafer, placing the wafer on a transparent chuck, directing alignment beam through the transparent glass chuck and then redirecting alignment beam to strike the alignment marks (see col. 3, lines 60-67)" as summarized by the Examiner.

With respect to claims 19-21, 23, 26-28, and 30-32, applicants note that Elliott et al. teach a method by which the alignment system directs the alignment beam 108 (see Fig. 5 and col. 6, lines 4-10) through an exposed edge of the vacuum chuck 10 to strike a reflective layer 100 on bottom surface of chuck to specifically strike and mark alignment targets on the back of wafer 106.

Because Elliot et al. specifically teach employing reflection to impinge the backside of a wafer, there is no reason to suggest the combination of Elliot et al. with the other cited references, which do not suggest applicants' claimed method. Nevertheless, applicants have amended claims 19, 26-29, 32, and 33 to recite that the chuck surface is nonreflective to the laser outputs <u>traveling through the through hole or through cut</u>. Elliot et al do not appear to contemplate through hole drilling or through cutting or avoidance of damage caused by laser pulses traveling through such holes or cuts. Backside damage is a substantial problem for the laser processing of semiconductors which are drilled or cut through when the laser processing beam continues emitting pulses. Reflected power from the chuck can then damage the backside of the wafer since the laser is increasingly defocused upon this reflection—meaning, simply, that the reflected light strikes a wider cross-sectional area than the incidence beam, and therefore does not merely reflect out through the formed hole or cut.

Applicants note that Elliot et al. do not appear to be germane at all to claims 24, 25, and 31, which do not recite a chuck surface.

With respect to claims 22, 29, and 33, the Examiner states that "because Elliott et al. ('997) teach a glass vacuum chuck, it is submitted that glass (silicone) absorbs laser light in the ultraviolet region." Elliott et al. teach the use of transparent chuck materials having a reflective bottom surface. Elliott et al. specifically teach use of Pyrex, quartz, or fused silica (see col. 4, lines 51-56). Quartz and fused silica are commonly used transmissive

optical materials at 355 nm (The Examiner is directed to the Handbook of Optical Constants of Solids, edited by E. Palik, Academic Press (1985) p.719 and p.74, respectively). In view of the foregoing or the amendments made to claims 19, 29, and 33, the disclosure of Elliot et al. is moot with respect to these claims.

Applicants request therefore, the rejection of claims 19-33 be withdrawn.

Claims 1-3, 11, and 15-17 stand rejected under 35 USC 103(a) as being unpatentable over Smith et al. in view of Cutler et al. and further in view of Owen et al. Applicants respond to this rejection as follows.

Smith et al. preferably employ a KrF excimer laser ($\lambda = 248$ nm, see Table 1.1 in Ultraviolet Lasers, W. W. Duley, pg. 5, (1996) Cambridge Press, Cambridge) to pattern an array of ink jet nozzles by imaging the laser output using a computer generated hologram. Smith et al. also suggest that other lasers could be used, and they specifically mention a YAG or a doubled YAG (col. 7, lines 51-53). Smith et al. teach that use of this method can form nozzles in a variety of materials, including alumina, silicon, and stainless steel (col. 4, lines 19-21). Smith et al. further teach that silicon processing requires a working image of about 3 joule/cm^2 (col. 13, line 45).

With respect to claims 1, 2, 11, and 17, the method proposed by Smith et al. is a completely different process than claimed by applicants and requires an imaging technique to make the process work. While applicants can optionally use a mask merely to refine the shape of the single spot emitted by the laser. The imaging mask technique as taught by Smith et al. also relies on linear advance of the workpiece, such as a ribbon format (col. 9, line 14) and web advancement methods well known to the art (col. 9, lines 19-23). Such methods are incompatible with the laser processing method claimed by applicant and are incompatible with employment with the beam positioning system described by applicant (applicant col. 3, paragraph 0039). There would be no motivation to combine Smith et al. and Cutler et al., and the method of Smith et al. cannot reasonably be adapted for use in the system of Cutler et al.

Applicants also believe that the Smith et al. teaching about a YAG or a doubled YAG teaches away from applicants' claimed process because Smith et al. prefer an excimer that emits in the UV, but only mention YAG in a nonUV context. Furthermore, Smith et al. do not describe how the Gaussian output of YAG could be adapted for a process that appears to rely on a nonGaussian excimer output. Applicants also note that

Smith et al. do not appear to mention a repetition rate as now recited in the base claims 1, 2, and 11.

Since Smith et al. in view of Cutler et al. do not suggest the claimed process of micromachining silicon using a pulsed UV laser system, then the observation that Owen et al. teach a pulsed UV laser system generating a spot size of 25 microns does not make obvious claims 1-2, and 11.

Applicants respectfully disagree with the Examiner's suggestion that "by calculating the pulse energy as the product of the power density and spot area, the pulse energy is more than 200 μJ," where the Examiner has noted that Smith et al. "teach a power density of 3 J/cm^2" and Owens et. al. teach a spot size of 25 microns. Applicants compute this assertion using a well-known formula as follows:

Fluence (J/cm^2) = {Energy per pulse (J)}/{π x [spot size (cm)/2]^2}

or: Energy per pulse (J)=Pulse Energy Density (J/cm^2)x{π x [spot size (cm)/2]^2}

which gives

Energy per pulse (J)=3 J/cm^2 x {π x [12.5 x 10^{-4} cm]^2}=1.47 x 10^{-5} J or 14.7 μJ.

Therefore, applicants submit that fluence of 3 J/cm^2 for formation of nozzles in silicon using the imaging mask method taught by Smith et al. in view of the spot size of 25 microns taught by Owen et al. does not teach to the process parameter of 100 μJ in applicants claims 1-2, and 11. Applicants further note that Owen et al. appear to describe processing different materials.

Applicants further note that the Examiner references his same inaccurate calculation with respect to claims 15 and 16. Applicants submit that claims 15 and 16 are not suggested by Smith et al. in view of Owen et al. as shown by applicants' calculation of fluence shown above.

With respect to claim 3, the Examiner suggests that Smith et al. teach the use of at least five pulses. Applicants could not find any mention of the number of pulses employed by Smith et al. to create nozzles in silicon. Applicants note, however, that it is well-known to the art that laser processing using excimer mask methods are often performed with as few as one or two pulses (see Ultraviolet Lasers, W. W. Duley, pg. 200-203, (1996) Cambridge Press, Cambridge). Applicants do not disagree that it is possible that Smith et

al. may employ more than five pulses, but Smith et al. do not appear to disclose such a method. The other claimed parameters make this rejection moot.

Applicant request, therefore, that the rejection of claims 1, 2, 11, and 15-17 be withdrawn.

Claims 4-10, 19-22, 31-33 stand rejected under 35 USC 103(a) as being unpatentable over Smith et al. in view of Cutler et al. and in further view of Owen et al. and Elliott et al. Applicants respond as follows.

The limited significance of Smith et al. in view of Cutler et al. and in further view of Owen et al. have been described above. The limited relevance of Elliot et al. has also been described above.

Nevertheless, claims 19 (from which claims 20-22 depend), 32, and 33 have been amended as previously discussed and overcome any use of Elliot in combination with other references. Claim 6 (from which claims 7-9 depend) has also been amended to recite that the chuck surface is nonreflective to the laser outputs <u>traveling through the through hole.</u>

In view of the limited relevance of Smith et al. and Owen et al., claims 4, 5, and 10, which depend on the process parameters and materials of claim 2, are not suggested by the combination of references.

Similarly, independent claim 31 recites process parameters and materials whose combination is not suggested by the Examiner's cited art. Nevertheless, claim 31 is amended to recite a repetition rate of greater than 5 kHz to be consistent with the other base claims.

With respect to claims 9, 22, and 33, the suggested absorbance of glass in the UV has be shown to be inaccurate, so this rejection should be withdrawn.

Applicants request, therefore, that the rejection of claims 4-10, 19-22, and 31-33 be withdrawn.

Claims 12-14 stand rejected under 35 USC 103(a) as being unpatentable over Smith et al. in view of Cutler et al. and in further view of Owen et al. and Piwczyk et al. Applicants respond to this rejection as follows.

The limited significance of Smith et al. in view of Cutler et al. and in further view of Owen et al. have been described above. Similarly, the limited relevance of Piwczyk et al. has also been described above. There is no motivation to combine Piwczyk et al. or

Smith et al. with Cutler et al. or Owen et al. and applicants believe that such combination would be inoperable.

Claims 38-42 have been added to depend directly or indirectly from claim 1. Claims 38-42 recite the dependent subject matter of claim 12-16. Claims 43-71 are groups of dependent claims that should be allowable if the base claims are allowed.

Applicants believe that the application is in condition for allowance and respectfully request the same.

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